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Part 3

ASH AND SLAG HANDLING

3.7. Analytics

3.7.9. FBC ash – production and utilization

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ABSTRACT

Implementation of fluidized bed technology in utility power plants and CHP plants introduced conditions for effective desulphurization of flue gases and higher efficiencies of thermal processes, allowing at the same time for using also low calorific value waste and biomass besides traditional fuels. Combustion processes occurring in the presence of limestone, at temperatures lower than in pulverized-fuel or layered furnaces, are affecting also the quality of combustion by-products. Resulting FBC ashes differ from the traditional ashes in terms of their chemical and physical properties.

Completed research and implementation projects proved a high raw-material potential of FBC ashes, amongst others for production of building materials, civil engineering works and in preventive measures in the underground mining, the latter being confirmed by mass-scale use.

Optimum handling of FBC ashes may be provided by their granulation, resulting in the creation of a material which may be stored without environmental impact and loss of usable properties, and which may be directly used for the production of aggregates.

1. PRODUCTION OF FBC ASHES

Specifics of fluidized bed combustion include: very good oxygen-supply for burned grains of fuel, effective heat exchange, low temperature process (below 950 °C) and permanent capture of sulphur oxides by calcium compounds, which all allow for combusting not only the traditional solid and liquid fuels, but also biomass, waste and low-calorific materials, also those with considerable sulphur contents. Development of techniques and technologies of fluidized combustion allowed for increasing efficiencies and for constructing high-capacity blocks, and at the same time for desulphurizing of flue gases. In the result of combustion of fuels in the presence of limestone under these conditions, certain combustion by-products arise in form of flyash and bottom ash (slag).

In Poland, more than ten large power and CHP circulating fluidized layer blocks are in operation, as well as scheduled soon for operation the largest in the world block of 460 MW_e capacity ($\eta \approx 45$ %) [1, 2]. Used fuels include hard coal, lignite, coal muds and biomass. In recent years, the fluidized processes of power and heat generation were resulting in more than 1 mln t of CCPs produced annually– Table 1.

2. CHARACTERISTICS OF FBC ASHES

FBC ashes differ markedly from ashes arising from pulverized-fuel and stoker boilers. Their volume is increased by the presence of calcium compounds from decarbonization of limestone and from reactions with sulphur compounds.

Table 1. **Production and utilization of CCPs in Poland in 2000[1] [3]**

Item	Coal combustion products			Fly ash and slag from FBC		
	total	hard coal	lignite	hard coal	lignite	total
Production (thou t)	16 621	10 196	6 425,6	418,4	368,0	786,4
Utilization (thou t)	12 143	8 297	3 846,0	409,5	368,0	777,5
%	73,0	81,4	59,8	97,9	100,0	98,9
Directions of utilization, (thou t)						
- cement production	1 373	1373	0,0	14,0	0,0	14,0
- building materials	3 452	952	2,5	23,2	0,0	23,2
- brick and ceramics	506	506	0,0	0,0	0,0	0,0
- light aggregate	101	101	0,0	0,0	0,0	0,0
- roads, civil eng.	232	232	0,0	1,4	0,0	1,4
- mining	6 135	3 525	2 610,0	291,0	0,0	291,0
- land reclamation	2 220	1 014	1 205,5	78,9	368,0	446,9
- other	455	427	28,0	0,0	0,0	0,0
- temporary stockpile	167	167	0,0	1,0	0,0	1,0
Landfill, thou t	4 478	1 899	2 579,7	-	-	-
%	27	18,6	40,2	-	-	-

[1] production of FBC ashes in 2002 – 1.044 thou t; in 2005 – 1.304 thou t

Fundamental differences, resulting from reactions of combustion products with calcium compounds as well as the lower ranges of combustion temperature (850…950 ^{o}C), relate to: chemical composition of mineral part, content of calcium compounds, mineralogical composition, morphology and granulometry, as well as chemical reactivity (binding properties – hydraulic and pozolanic). FBC ashes are of calcareous type and to some extent similar in their properties to some calcareous ashes derived from lignite [4].

Observed qualitative and quantitative differences between CCPs show bigger amounts of FBC ashes and different composition and chemical-physical properties. These facts make it different, sometimes even impossible, to relate directly to the previous experience with ashes and slags from pulverized-fuel and stoker furnaces. In majority of cases, optimal management of FBC ashes requires developing individual methods of their storage and utilization.

From the point of view of conditions of storage and utilization, water-solubility of FBC ashes is an important parameter, as illustrated in Fig. 1. Depending on used test methods, the solubility of FBC ashes was higher than of traditional ashes, and in the presented case was 4,6 to 4,9 higher for flyashes, and even greater for slags, being in the range of 6,5 to 11,0 times higher.

The presence of active calcium compounds (CaO, $CaSO_4$) and aluminosilicates in FBC ashes decides on their hydraulic and pozolanic properties, which amongst others results from the following chemical reactions taking place:

$$2CaSO_4 \cdot 0{,}5H_2O + 3H_2O = 2CaSO_4 \cdot 2H_2O$$
$$CaO + CO_2 = CaCO_3$$
$$CaO + H_2O = Ca(OH)_2$$
$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$$

Usually bottom ashes are more active than flyashes. Binding properties of FBC ashes can be increased by their activation; mechanical (milling), hydrothermal and chemical (CO_2, adding binders).

Mixing flyash with bottom ash (slag) is reducing their binding properties, but such a strategy may nevertheless be purposeful for obtaining materials resistant to the impact of water and wind erosion.

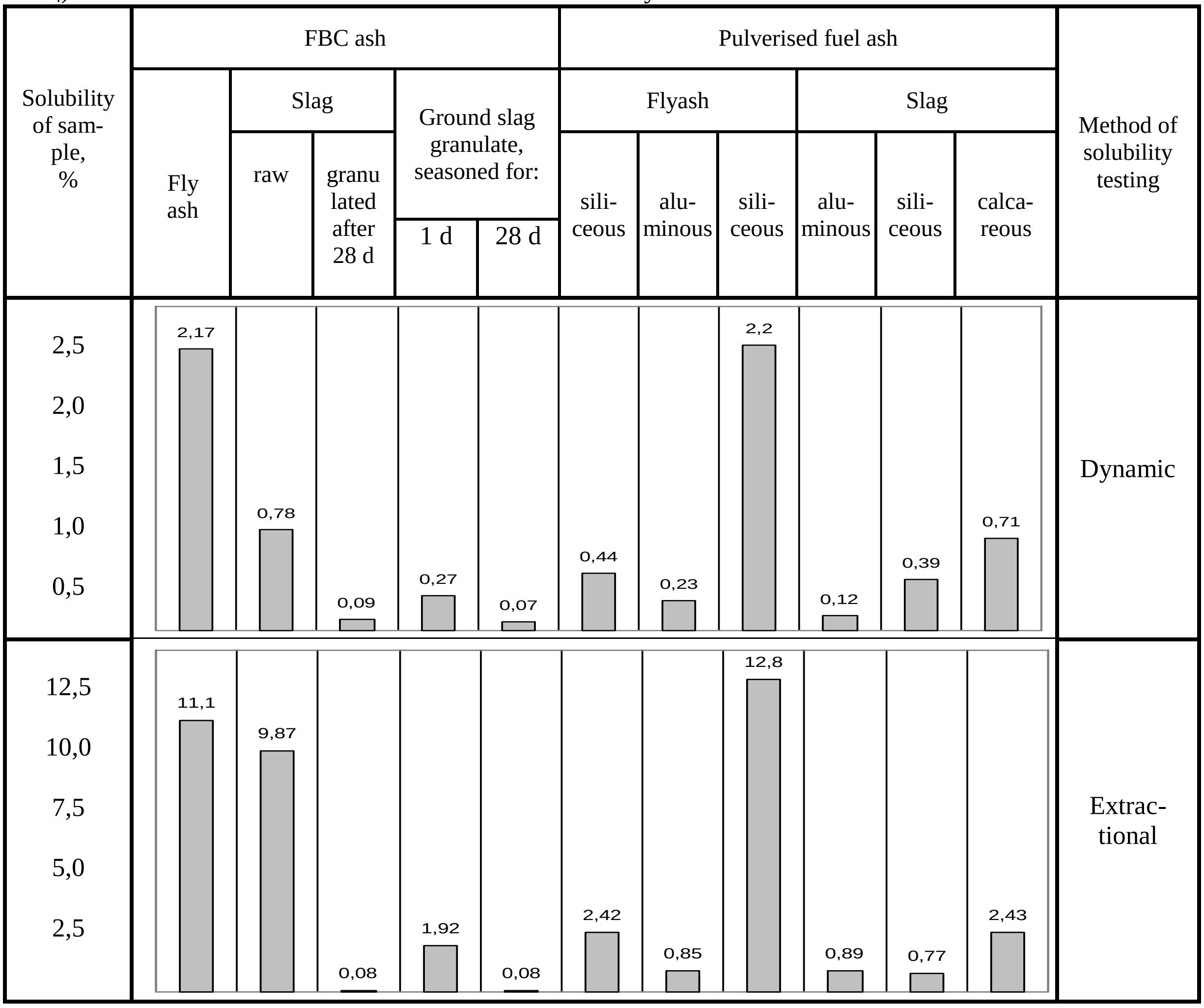

Fig. 1. Comparison of water-solubility of hard coal combustion products from FBC and pulverized-fuel boilers [1].

Tests made on granulates obtained from mixing flyashes and slags from FBC furnaces revealed the tendency for a linear relationship between the compressive strength of granulate and the content of calcium compounds – (Fig. 2)

Binding ability of a system with FBC ashes and a precise amount of water is affecting not only their strength parameters (impact resistance, compressive and flexural strength) but also their resistance to water erosion (Fig. 1) and wind erosion (elimination of dusting).

3. DIRECTIONS OF UTILIZATION OF FBC ASHES

Physical and chemical composition of FBC ashes allows for such ways of utilization, which increase the effective use of:

- fuel,
- limestone,
- mineral raw materials,
- hydraulic and pozolanic activity,
- safe storage suitability.

By turning carbon-rich fractions of ash back to the combustion chamber, a higher fuel efficiency is achieved. Based on the same principle, usually bottom ash is turned back in

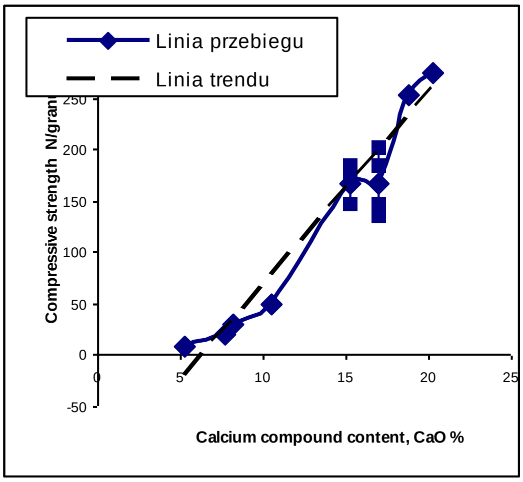

Fig. 2. Influence of content of calcium-compounds on compressive strength of granulated FBC ash

order to utilize the un-reacted limestone. In order to increase their reactivity, the returned ashes are activated mechanically before. Such approach is increasing the effectiveness of fuel and limestone utilization, while decreasing the volume and stabilizing the properties of FBC ashes.

The presence of active chemical compounds in FBC ashes is decisive for their potential for being a substitute or/and a raw material for the production of binders, building materials, sorbents and ionic exchangers, as well as structural fill, which is illustrated in Table 1. The biggest volumes of FBC ashes are utilized in civil engineering and mining works, most often as components of mixes used for a particular application (water- and gas barriers, structural infills, etc.). In recent years, it is possible to observe an increase in the use of FBC ashes in binders without - or with a minimum content of cement, mainly for road construction applications. Also artificial aggregates are produced based on FBC ashes in low-temperature technologies.

In some countries FBC ashes are used in treatment of soils polluted with heavy metals and for lime-treatment of acidic soils, as well as for the neutralization of acid sewage and industrial wastes.

Unutilized FBC ashes are stockpiled for future use. Due to a heavy load of water-soluble constituents, FBC ashes require special care. Most often they are mixed together with traditional ashes and only then stocked. In Canada a technology is used, involving preparation of ash-water suspension, which is bleeding-free and sets completely when placed on a landfill.

From the point of view of ensuring conditions for safe storage, while keeping the possibility of future use of FBC ashes, the granulation technology is highly significant. Due to the actions of centrifugal and adhesion forces, coupled with chemical reactions occurring in the presence of controlled amounts of water, solidified granules are created, having new physical properties and practically the unchanged chemical composition. Tight packing of ash grains in the granules, as well as occurring chemical processes, reduce the leachability of compounds by water (Fig. 1), while increasing the compressive strength of produced granules – Table 2.

Table 2. **Strength characteristics of granulated FBC ash**

Mix % mass		Compressive strength N/granule after			
Flyash	Slag	3 d	7 d	14 d	28 d
0	100	18,5	55,2	133,5	167,7
100	0	0,1	0,1	2,0	1,8
95	5	0,0	10,3	16,6	19,3
90	10	0,0	15,0	28,9	36,7
85	15	3,1	16,0	33,4	41,8
80	20	5,6	18,4	39,6	48,5
75	25	2,9	28,8	68,5	83,3
70	30	9,7	32,0	76,9	97,7

Research and trials demonstrated, that granulation of FBC ashes is bringing about:

- more possibilities of utilization,
- less pollution of the environment,
- possibilities of treating the deposited ashes as a - neutral for the environment raw material - for a range of technologies.

4. CONCLUSIONS

Implementation of fluidized bed boilers in power plants and CHP plants created conditions for effective desulphurization of flue gases and increasing the efficiency of thermal processes, opening at the same time possibilities of using refuse-derived fuels and biomass, together with traditional fuels.

Differences in fluidized combustion of fuels, when compared with pulverized-fuel and layered furnaces (among others: lower temperatures of combustion, presence of limestone) are affecting the qualities of resulting solid combustion products. Arising FBC ashes are markedly different in their chemical and physical composition from traditional ashes.

Research, trials and implementation projects demonstrated a high raw-material capacity of FBC ashes, which led to their mass-scale utilization.

Granulation is very beneficial for optimizing the utilization of FBC ashes, resulting in a material which is not impacting on the environment when stored, while allowing for future utilization and suitability for direct manufacture of aggregates.

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